MODULE 4 - FOODBORNE BACTERIAL PATHOGENS AND THERMAL DESTRUCTION

Objective

On completion of this module, participants will be able to:

- Identify the primary public health controls for some bacteria that are major causes of foodborne illness
- Define D value
- Relate the D value to the cooking temperatures required by the Food Rules
- Define pasteurization as normally used for food

Overview

Modules 1 and 2 provided an overview of microbiology. This module will be specific and discuss various foodborne bacterial pathogens. The bacterial pathogens can be broken into two groups: (1) gram-negative rods, and (2) gram-positive rods and cocci. The pathogens within each group have some similarities in addition to the way they stain. For example, gram negative rods are nonspore formers and tend to have a fecal source. On the other hand, gram-positive rods and cocci can be spore formers and are typically associated with environmental sources like soil and sediments.

Gram Negative Rods

The **gram-negative rods** covered in this module are: ***Campylobacter jejuni*, *Yersinia spp.*, *Salmonella spp.*, *Shigella spp.*, *Escherichia coli* and *Vibrio spp. , Plesiomonas shigelloides***

Gram Positive Rods

The **gram-positive rods** and **cocci** covered in this module are: ***Bacillus cereus*, *Listeria monocytogenes, Clostridium perfingens, Clostridium botulinum, Staphylococcus, Streptococcus, Aeromonas hydrophila, Miscellaneous enterics***

BETC participants are not expected to know microorganisms by Gram type, this is provided for information only.

This section contains background information on specific foodborne bacterial pathogens. An understanding of the growth characteristics and sources of bacterial pathogens in foods is essential to conducting a hazard analysis of a food product.

The CONTROLS and RESERVOIR for those bacterial agents you are most likely to investigate as associated with a food borne illness are below. The web address indicated for each microorganism is for additional information about the microorganism.

Pathogenic bacteria

- ***Campylobacter jejuni***
  http://vm.cfsan.fda.gov/~mow/chap4.html
- CONTROLS FOR CAMPYLOBACTER JEJUNI: Sanitation to prevent recontamination (including handwashing and prevention of cross contamination); cooking; pasteurization; water treatment
- RESERVOIR: Chickens; cows; flies; cats; puppies.
- ***Yersinia enterocolitica* and *Yersinia pseudotuberculosis***
  http://vm.cfsan.fda.gov/~mow/chap5.html
- CONTROLS FOR YERSINIA: Sanitation to prevent recontamination (including handwashing and prevention of cross contamination); cooking; pasteurization; water treatment; proper holding temperatures.
- RESERVOIR: Animals and their feces; lakes; streams; vegetation; soil; birds.
- ***Salmonella* spp.** http://vm.cfsan.fda.gov/~mow/chap1.html
- CONTROLS FOR SALMONELLA: Sanitation to prevent recontamination (including handwashing and prevention of cross contamination); cooking; pasteurization; proper holding temperatures.
- RESERVOIR: Domesticated animals and feces; water; soil; insects.
- ***Shigella* spp.** http://vm.cfsan.fda.gov/~mow/chap19.html
- CONTROLS FOR SHIGELLA: Sanitation to prevent recontamination (including handwashing and prevention of cross contamination); cooking; water treatment; proper holding temperatures.
- RESERVOIR: Humans, for all practical purposes.

Enterovirulent Escherichia coli Group (EEC Group)

The EHEC group is the one of most interest for Public Health Environmentalists; this group includes E. coli O157:H7. The other groups below are presented for information.

- ***Escherichia coli* - enterotoxigenic (ETEC)**
  http://vm.cfsan.fda.gov/~mow/chap13.html
- ***Escherichia coli* - enteroinvasive (EIEC)**
  http://vm.cfsan.fda.gov/~mow/chap16.html
- ***Escherichia coli* - enteropathogenic (EPEC)**
  http://vm.cfsan.fda.gov/~mow/chap14.html
- ***Escherichia coli* O157:H7 enterohemorrhagic (EHEC)**
  http://vm.cfsan.fda.gov/~mow/chap15.html
- CONTROLS FOR EHEC: Sanitation to prevent recontamination (including handwashing and prevention of cross contamination); cooking; pasteurization; personal hygiene; proper holding temperatures; preventing fecal contamination of animal carcasses.
- RESERVOIR: Some ruminants; e.g., cattle; some other animals. Can be spread person-to-person.
- ***Vibrio cholerae O1*** http://vm.cfsan.fda.gov/~mow/chap7.html
- ***Vibrio cholerae non-O1*** http://vm.cfsan.fda.gov/~mow/chap8.html
- ***Vibrio parahaemolyticus* and other *vibrios***
  http://vm.cfsan.fda.gov/~mow/chap9.html
- ***Vibrio vulnificus*** http://vm.cfsan.fda.gov/~mow/chap10.html
  NOTE THE CASE FATALITY RATE FOR V. VULNIFICUS DISEASE IS 50%. ALSO, V. VULNIFICUS IS A NATURAL COMPONENT OF WARM MARINE WATERS, IT IS NOT AN INDICATOR OF, OR ASSOCIATED WITH, POLLUTION OF THE SHELLFISH GROWING WATERS.
- CONTROLS FOR VIBRIOS: Cooking; prevention of recontamination; prevention of time/temperature abuse; control product source.
- RESERVOIR: Estuarine waters.
- ***Plesiomonas shigelloides***
  http://vm.cfsan.fda.gov/~mow/chap18.html
- ***Bacillus cereus*** http://vm.cfsan.fda.gov/~mow/chap12.html
- CONTROLS FOR BACILLUS CEREUS: Refrigeration.
- RESERVOIR: Widely distributed in the environment.
- ***Listeria monocytogenes***
  http://vm.cfsan.fda.gov/~mow/chap6.html
- CONTROLS FOR LISTERIA MONOCYTOGENES: Sanitation to prevent recontamination from the environment; cooking; pasteurization.
- RESERVOIR: Soil; other environmental sources.

- ***Clostridium perfringens***
  http://vm.cfsan.fda.gov/~mow/chap11.html
- CONTROLS FOR C. PERFRINGENS: Proper cooling, holding, and reheating; education of food handlers.
- RESERVOIR: Humans; domestic and feral animals; soil; sediment.
- ***Clostridium botulinum*** http://vm.cfsan.fda.gov/~mow/chap2.html *NOTE THAT C. BOTULINUM TOXIN IS A NEUROTOXIN; ALSO NOTE THE ASSOCIATED FOODS AND INFECTIVE DOSE.*
- CONTROLS FOR C. BOTULINUM: Destruction of spores; thermal processing; approved source.
- RESERVOIR: Soil; fresh-water and marine sediments; fish; mammals.
- ***Staphylococcus aureus***
  http://vm.cfsan.fda.gov/~mow/chap3.html *NOTE THAT S. AUREUS TOXIN IS NOT DESTROYED BY ANY HEAT PROCESS ASSOCIATED WITH STANDARD COOKING TEMPERATURES.*
- CONTROLS FOR S. AUREUS: Heating; proper employee hygiene; prevention of temperature abuse.
- RESERVOIR: Primarily humans; but also animals; air; dust; sewage; water.
- ***Streptococcus*** http://vm.cfsan.fda.gov/~mow/chap21.html
- ***Aeromonas hydrophila* and other spp.**
  http://vm.cfsan.fda.gov/~mow/chap17.html
- **Miscellaneous enterics**
  http://vm.cfsan.fda.gov/~mow/chap20.html

IMPORTANT POINTS FOR PUBLIC HEALTH ENVIRONMENTALISTS: The common CONTROLS for any microorganism are effective for other microorganisms. That is, PREVENTION OF RECONTAMINATION as a step to control Campylobacter jejuni will also be effective against contamination by Yersinia or any other microorganisms for which this is a control. Proper handwashing to prevent contamination by Salmonella will also prevent contamination by Shigella spp.

BETC participants are not expected to know details of specific microorganisms; however general control mechanisms should be known. That is, participants should know that prevention of temperature abuse is a common control mechanism, they do not have to know which microorganisms for which it is a control.

Thermal destruction of bacteria

For the temperatures we find in normal kitchen operations, or even food processing operations, there is no such thing as microbiological "zero." At a given temperature for a given time, the numbers of bacteria are reduced by a

percentage amount. The exponential reduction in numbers of bacteria is referred to by D values.

D value indicates the time required to destroy 90% of the bacterial cells at a given temperature.

For example, you hold a theoretical pathogen at 180°F and start with 1,000,000 (10^6) cells. At the end of 8 minutes, the number of bacterial cells has been reduced to 100,000 (10^5), after another 8 minutes to 10,000 (10^4) and after 8 more minutes to 1,000 (10^3) and so on. This is a typical pattern for bacterial destruction by heat; the bacteria die off logarithmically. The D value is given for a particular temperature; in this example, D_{180} = 8 minutes.

For cooking temperatures, the microorganism usually used to determine D values is Salmonella. Reducing the number of Salmonella organisms from 10^6 to 10^1 is a 5D reduction. The cooking temperatures of the Food Rules are designed to achieve

145°F for 15 seconds:	3D reduction (99.9%)
155°F for 15 seconds:	5D reduction (99.999%)
165°F for 15 seconds:	7D reduction (99.99999%)

The explanation for the higher cooking temperature for poultry is that the expected bacterial load is higher and this time-temperature combination will reduce that higher load to a safe, non-infective level, not just because Salmonella can be expected to be found on raw chicken. Salmonella can be expected to be found on any raw food from an animal source; the determining factor for a pre-designated cooking temperature is the expected numbers at which it can be found.

For most foods, when a time-temperature combination achieves a 5D reduction in Salmonella sp., the food has been “pasteurized”. Time must be considered with temperature in determining the D reduction: the higher the terminal temperature, the less time the food must be held at that temperature to achieve an equivalent kill.

NOTE: Pasteurization as it refers to milk has a D value established by the Milk Rules (Pasteurized Milk Ordinance) and some other foods may have a very specific meaning of “pasteurized.”

Commercial canning operations must reach a time-temperature combination to give a 12D reduction. This can only be done under pressure cooking and is referred to as being “commercially sterile”. There are still some spores even in canned products that can become vegetative when heat shocked, such as being stored at above 140°F.

The Z value is also referred to when designing a thermal destruction process for food. The Z value is the temperature change needed to change the D value by one log. The Z value lets you compare or convert the lethality of a period of time at one temperature to the lethality of the same length of time at another temperature.

From the D value example above (D_{180} = 8 minutes) it takes 8 minutes at 180°F to reduce the bacterial load by one log. For our theoretical example then, we want to know the temperature necessary to reduce the bacterial load by one log when held for 80 minutes (increase time by a factor of 10). If it takes 80 minutes at 165°F to reduce the same bacterial load by one log, the Z value is 15 (180 - 165). Different microorganisms have different Z values and Z values can be influenced by the products that are being processed.